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(54) **WEB CONNECTED DUAL AEROFOIL MEMBERS**

(71) Applicant: **ROLLS-ROYCE PLC**, London (GB)

(72) Inventor: **Andrew James Drane**, St George  
Bristol (GB)

(73) Assignee: **ROLLS-ROYCE plc**, London (GB)

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**F04D 29/38** (2006.01)

**F04D 29/02** (2006.01)

(52) **U.S. Cl.**

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**2230/53** (2013.01); **F05D 2300/603** (2013.01);  
**Y10T 29/49336** (2015.01)

(58) **Field of Classification Search**

CPC ..... F01D 5/14; F04D 29/388  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,098,559 A	7/1978	Price	
5,573,376 A *	11/1996	Hayden	F04D 29/321 29/888.025
5,725,353 A	3/1998	Matheny et al.	
5,735,673 A *	4/1998	Matheny	F01D 5/282 416/223 A
6,431,837 B1 *	8/2002	Velicki	F01D 5/282 416/223 R
7,121,805 B2 *	10/2006	Chang	F04D 29/34 416/210 R
8,956,487 B2 *	2/2015	Gallet	B29C 70/86 156/148
2009/0317246 A1 *	12/2009	Lutz	F01D 5/14 415/200

FOREIGN PATENT DOCUMENTS

FR 2 504 209 A1 10/1982

OTHER PUBLICATIONS

Jan. 4, 2013 Search Report issued in British Patent Application No.  
GB1215908.3.

\* cited by examiner

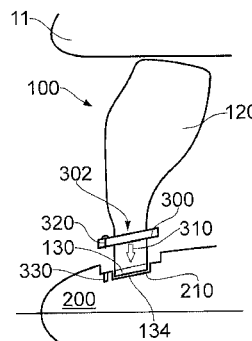
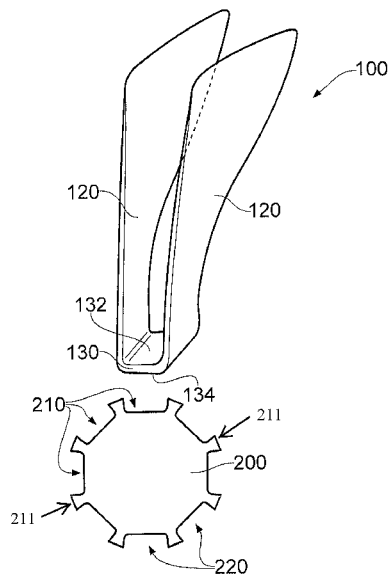
*Primary Examiner* — Mary A Davis

(74) *Attorney, Agent, or Firm* — Oliff PLC

(57) **ABSTRACT**

A rotor blade assembly for a gas turbine engine includes two  
aerofoil members joined together at their roots by a blade  
assembly attachment web. The rotor blade assembly is made  
from a composite material, for example an organic fiber  
composite material. The blade assembly attachment web is  
used to attach a plurality of rotor blade assemblies to the rest  
of the gas turbine engine in order to form a rotor stage. The  
rotor stage may, for example, be the fan stage of a turbofan  
gas turbine engine.

**10 Claims, 5 Drawing Sheets**



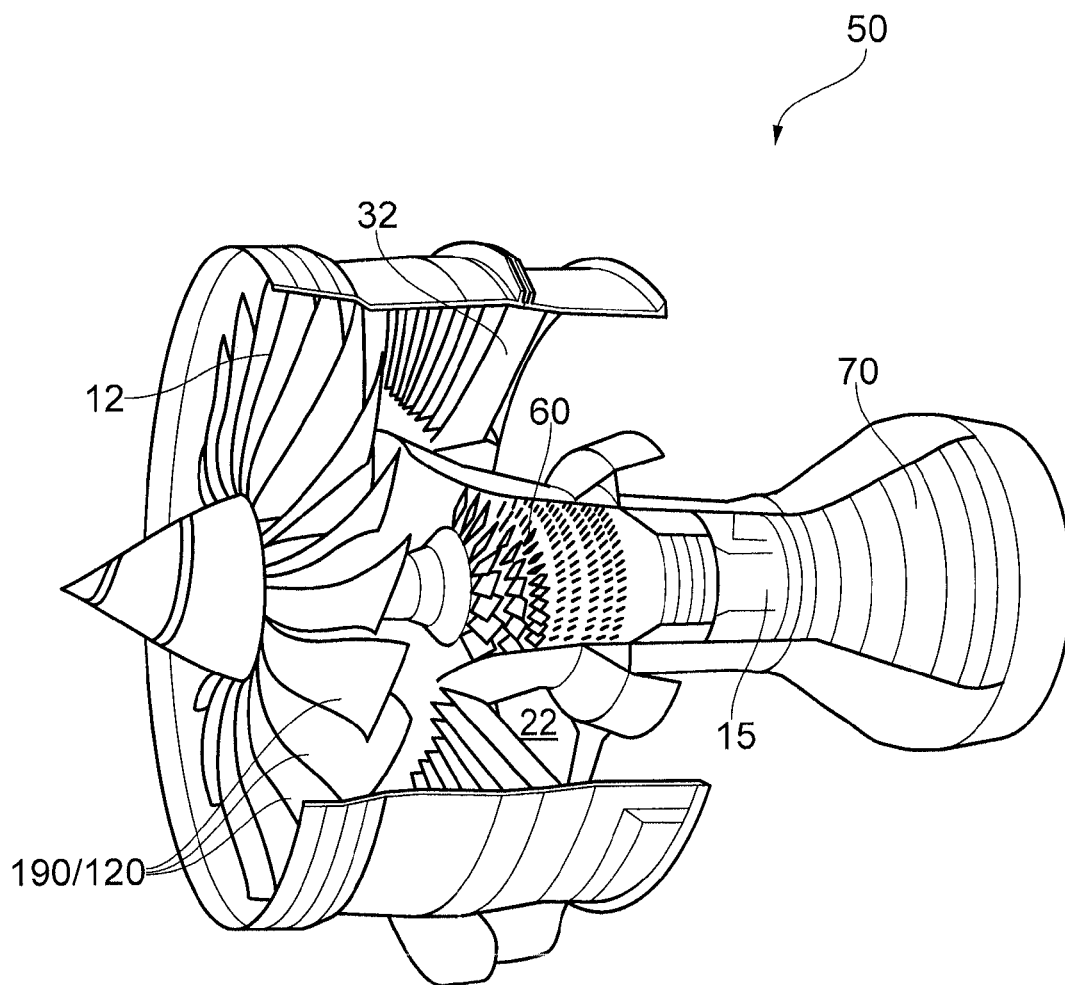


FIG. 1

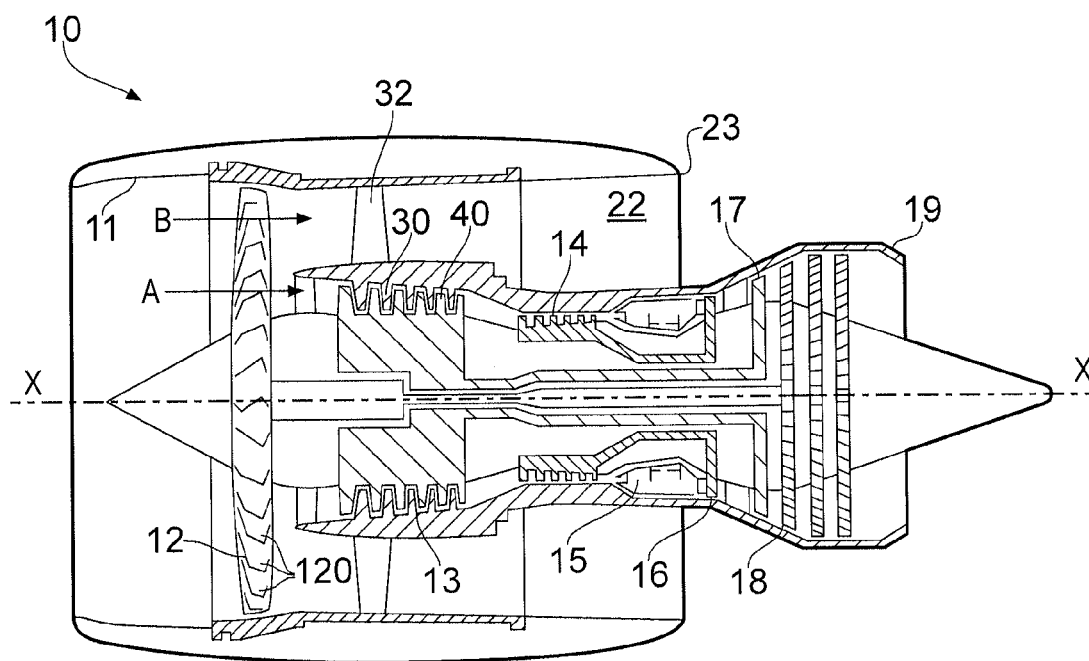


FIG. 2

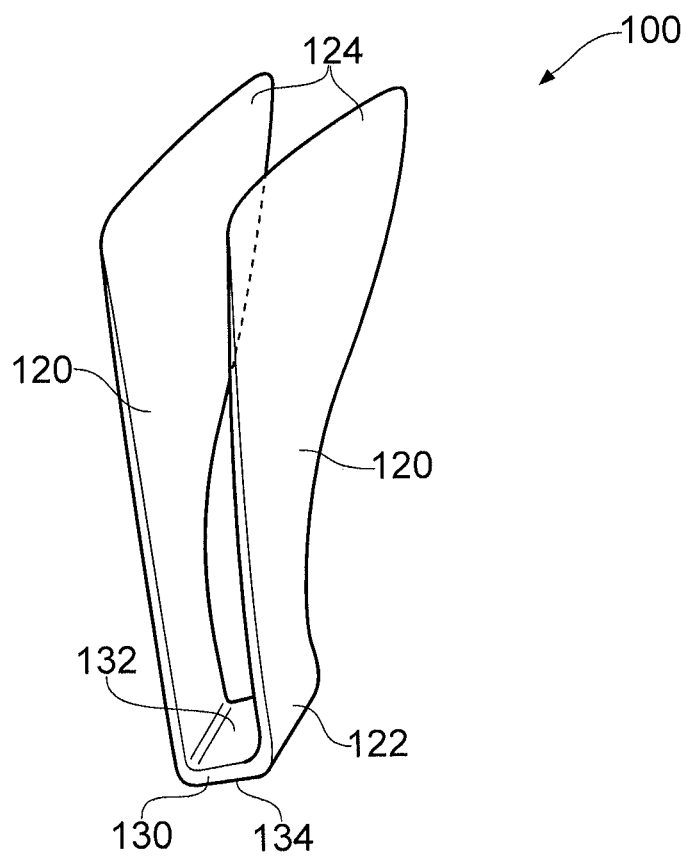


FIG. 3

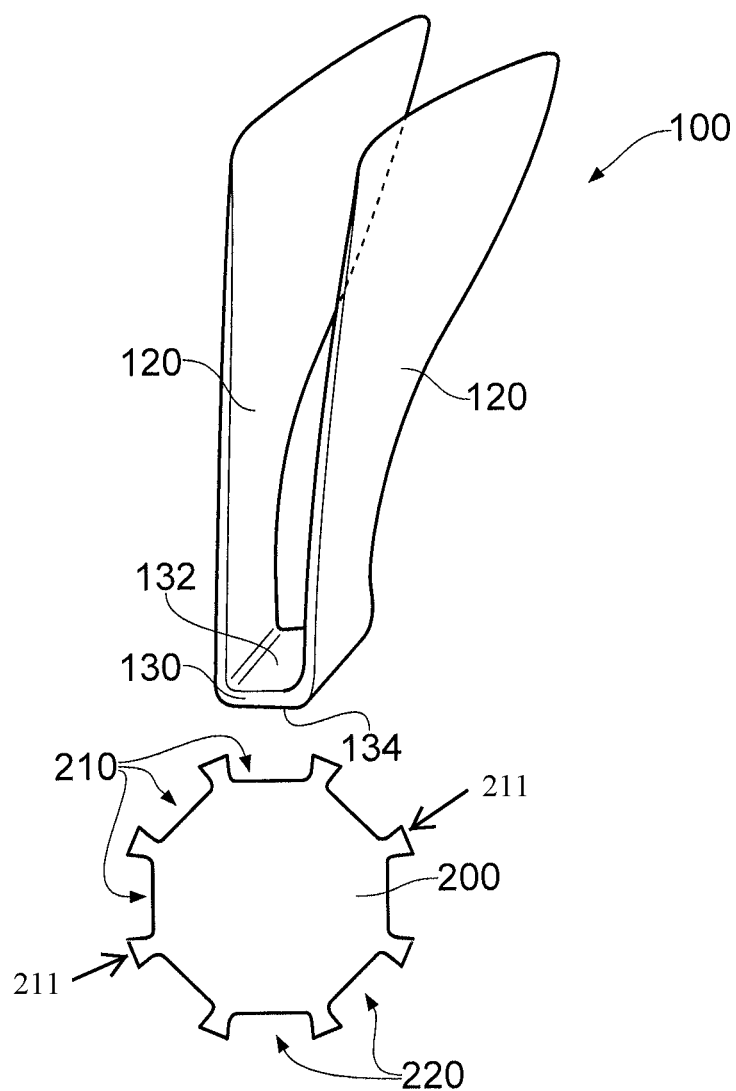


FIG. 4

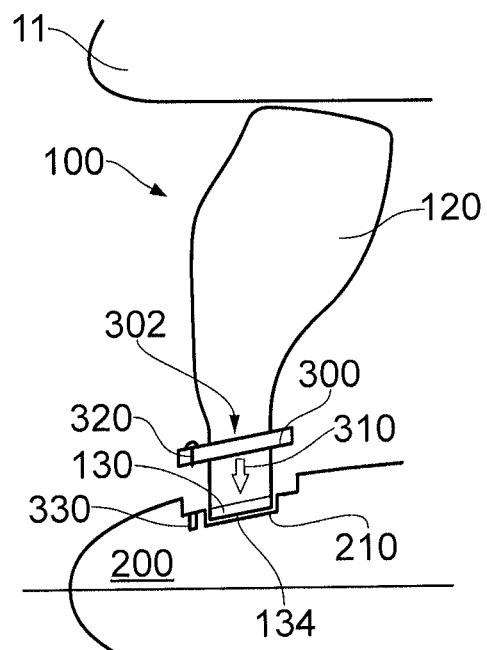


FIG. 5

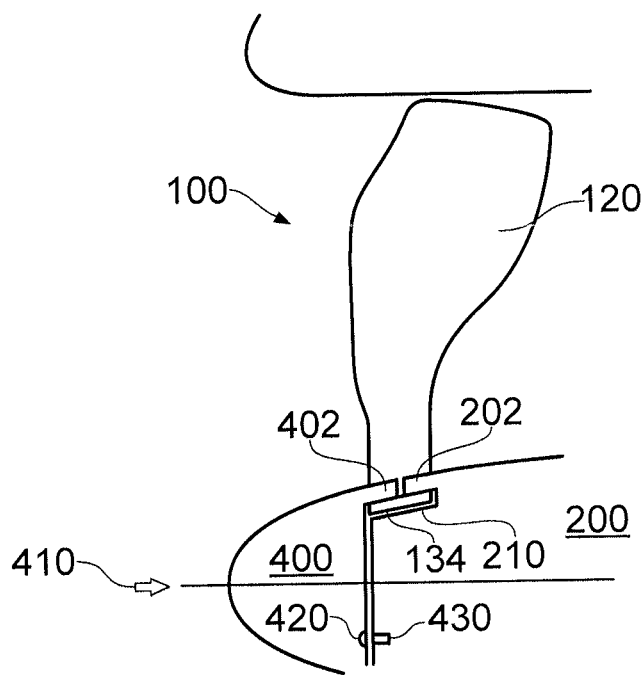


FIG. 6

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## WEB CONNECTED DUAL AEROFOIL MEMBERS

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from British Patent Application Number 1215908.3 filed 6 Sep. 2012, the entire contents of which are incorporated by reference.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to a rotor blade assembly for a gas turbine engine. In particular, aspects of the invention relate to a composite rotor blade assembly and arrangements for attaching composite rotor blade assemblies to a gas turbine engine.

#### 2. Description of the Related Art

An axially rotating gas turbine engine comprises a number of rotor stages and a number of stator stages, each comprising aerofoil members mounted around an engine axis. The rotor stages are arranged such that, in use, the aerofoil members rotate around the engine axis. The stator stages are arranged such that, in use, the aerofoil members are fixed in position around the engine axis. Conventionally, a gas turbine engine would have a compressor and a turbine, each of which would comprise at least one (and usually several) rotor and stator stages.

A cut-away diagram of an example of a turbofan (bypass) gas turbine engine **10** is shown in FIG. 1. The gas turbine engine **10** comprises, in axial flow series, a fan **12**, a compressor **60**, a combustor **15**, and a turbine **70**, each of which operates in a conventional manner. The compressor **60** and turbine **70** are conventionally referred to as being part of the core of the engine, and the flow from the fan **12** that does not pass through the core of the engine is said to pass through a bypass duct **22**.

The compressor **60** and turbine **70** both have rotor stages and stator stages. The fan **12** may be considered as a rotor stage, and may be referred to as a fan **12** or a fan stage **12**. In the FIG. 1 example, a stator stage **32** is provided in the bypass duct **22** for the flow that does not pass through the core of the engine. This stator stage in the bypass duct **22** may be referred to as an outlet (or outer) guide vane (OGV) stage **32**.

The fan **12** may be considered as a low pressure compressor. The fan **12** comprises a plurality of fan blades **120/190**. In FIG. 1, the fan blades **120/190** may either be conventional fan blades **190** or fan blades **120** in accordance with aspects of the invention. Conventionally, the fan blades **190** are metallic items that are manufactured as single pieces and then assembled onto a rotatable shaft. In order to fix the conventional fan blades **190** onto the rotatable shaft, a wedge shape is generally provided at an inner radius of each blade, which is then slid into position and secured in place during assembly. Such a wedge shaped fitting arrangement may be referred to as a dovetail fixture.

However, metallic fan blades **190** and the conventional arrangements for assembling metallic fan blades **190** to form a fan **12** are very heavy.

It is desirable to replace the conventional metallic fan blades **190** with lighter components. In turn, this would result in a lighter fan stage, and thus a lighter engine, and improved fuel consumption (or SFC).

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It is proposed to use a composite structure rather than a metallic structure to form the fan blades. Such a composite structure may have sufficient strength, but considerably lower weight than a conventional metallic fan blades. Composite fan blades may also be less expensive to manufacture than metallic fan blades.

However, conventional approaches to fixing the fan blades to the engine in order to form the fan may not be appropriate when using composite fan blades. For example, a dovetail style fixture may be difficult and/or expensive to form using a composite material whilst retaining the necessary strength and/or longevity of the fixture. Such a dovetail-type fixture may require a rapid build-up of thickness of the composite material in a particular area, making the manufacturing process more complex and potentially introducing weakness at ply drop interfaces.

Although much of the discussion above and elsewhere herein focuses on the fan blades and the fan stage, it will be appreciated that the same or similar considerations may apply to other rotor stages and blades therefor.

### OBJECTS AND SUMMARY OF THE INVENTION

It is therefore desirable to use composite blades (for example fan blades), and to be able to attach such composite fan blades to an engine in a suitable manner, for example a manner which is straightforward and/or lightweight and/or retains the material properties (such as strength and/or stiffness) of the composite blades.

According to an aspect there is provided a rotor blade assembly for a gas turbine engine. The rotor blade assembly comprises two aerofoil members extending from a root to a tip. The rotor blade assembly also comprises a blade assembly attachment web extending between the roots of the aerofoil members. The blade assembly attachment web is arranged for use in attaching the rotor blade assembly to the rest of the gas turbine engine in use. The two aerofoil members and the blade assembly attachment web are integrally formed using a fibre-reinforced composite material.

Such an arrangement may allow the use of composite aerofoil members in a rotor blade stage. The arrangement, including the blade assembly attachment web, may allow the aerofoil members to be attached to the engine (for example to a rotatable shaft) in a manner that retains the strength of the assembly, and is straightforward to manufacture and assemble. Accordingly, this may allow lightweight, strong, and/or robust fan blades to be used, resulting in lower weight and/or less expensive fan blades that may be more straightforward to assemble than conventional fan blades. The arrangement may thus be more appropriate for the use of composite materials than using individual blades with individual, and potentially complex, root fixtures.

As is conventional, the root may be said to be a radially inner portion of the aerofoil member and the tip may be said to be a radially outer portion of the aerofoil member. The root may thus be a root portion. In use, some or all of the root portion may not be exposed to the working fluid. In use, the rest of the aerofoil member, including the tip or tip portion, may be exposed to the working fluid. The aerofoil members may be referred to as blades, for example fan blades.

The blade assembly attachment web may be said to be constructed and/or arranged to allow the rotor blade assembly to be fixed in position in the rotor blade stage in use.

The fibre-reinforced composite material may comprise fibres that extend continuously through the rotor blade assembly. The continuous fibres may extend from the tip of

one blade to the tip of the other blade. The continuous fibres may extend from the tip of one blade, through the blade assembly attachment web, to the tip of the other blade. In such an arrangement, the continuous fibres may pass in a substantially radial direction from the tip to the root of one blade, then in a substantially circumferential direction through the blade assembly attachment web, then in a substantially radial direction from the root of the other blade to the tip of that blade. The terms radial and circumferential (and axial) used herein are defined in relation to a rotational axis of a gas turbine engine in which the guide vane assembly is to be fitted/used.

Use of continuous fibres may provide a particularly strong assembly. Furthermore, the strength may be provided in the required direction(s). Thus, for example, aligning fibres radially along the fan blades may provide strength in the radial direction, which may be subject to significant centripetal load during use.

The rotor blade assembly may comprise two and only two aerofoil members.

The fibre reinforced composite material may comprise some fibres that extend in a different direction to other fibres. Thus, not all the fibres may extend in the same direction. This may allow the strength of the assembly to be tailored to the loads that it experiences in use. Purely by way of example, some of the fibres may be arranged at particular angles to other fibres, such as in the range of from 10 degrees to 80 degrees, 20 degrees to 70 degrees, 30 degrees to 60 degrees, for example around 45 degrees.

Each aerofoil member of the rotor blade assembly may have both a pressure surface and a suction surface. Both the pressure surface and suction surface of adjacent aerofoil members in the rotor blade assembly may be formed at least in part using the same set of fibres. The same set of fibres may extend through the whole of both of the aerofoil members in the rotor blade assembly, as well as through the blade assembly attachment web.

The blade assembly attachment web may have a radially inner and a radially outer surface with respect to a rotational axis of the gas turbine engine in use. The radially inner surface may be shaped to cooperate with a mounting surface of the gas turbine engine to allow the rotor blade assembly to be located in position in the gas turbine engine. The radially inner surface may be in direct contact with the mounting surface.

The rotor blade assembly (for example at least a part of the aerofoil members) may comprise a protective coating. The protective coating may, for example, protect the aerofoil member/blade against erosion, which may occur for example due to particle impact during use. The protective coating may be provided over a part or all of the assembly, for example a part or all of the aerofoil members. The coating may comprise, for example a fluoroelastomer, polyetheretherketone and/or polyurethane.

At least a part of the outer surface of the assembly may be formed by a glass fibre skin (which may be woven). This may improve the impact toughness of the component. Additionally or alternatively, using a glass fibre skin on the blade assembly attachment web may help to provide galvanic insulation between the web and the component to which it is attached, for example if the web is a carbon composite structure and the component to which it is attached is metallic.

The aerofoil members may comprise a protective layer on the leading edge. Such a protective layer may or may not be in addition to any glass fibre skin provided to the assembly. This may provide additional protection against impact on the

leading edge of the aerofoil member, for example due to foreign object strike, such as a bird strike. Such a protective layer may take any suitable form, such as a metallic strip.

The aerofoil members may be aerofoil members of any rotor blade stage. For example, the aerofoil members may be fan blades. The rotor blade assembly may be a fan stage of a turbofan gas turbine engine. Because the fan blades are typically the largest and most complex rotor blades in an engine, the advantages (for example of light weight and simplicity) may be particularly beneficial when the aerofoil members are fan blades for a fan stage.

According to an aspect, there is provided a rotor blade stage of a gas turbine engine comprising at least one (for example a plurality) rotor blade assembly as described above and elsewhere herein. The rotor blade stage also comprises a rotatable hub portion. Each rotor blade assembly may be fixed to the hub portion. The blade assembly attachment web may form at least a part of the fixture of the blade assembly to the hub portion. Accordingly, a light-weight and easy to assemble rotor blade stage (such as a fan stage) may be provided.

The hub portion may be part of, or may be connected to, a rotatable shaft of the gas turbine engine. Such a rotatable shaft (and thus the hub portion) may be driven by a turbine of the gas turbine engine in use, either directly, or indirectly, for example through a gearbox.

In the event of damage to one of the rotor blade assemblies (for example damage to one of the aerofoil members, for example foreign object damage), only the damaged rotor blade assembly need be replaced. The rest of the rotor blade stage may remain untouched. Thus, the costs associated with the repair/overhaul of the stator vane stage may be reduced, and/or the repair/overhaul process may be simplified.

The hub portion may comprise a plurality of mounting surfaces. Each blade assembly attachment web may have a radially inner surface that is shaped to cooperate with a respective mounting surface. Thus, the blade assembly attachment web may be constructed and arranged to cooperate with the hub portion so as to locate each rotor blade assembly on the hub portion.

Each mounting surface may be formed by a radially inner surface (with respect to a rotational axis of the hub/engine) of a respective recess in the hub portion. Thus, the hub portion may have a plurality of recesses, with each rotor blade assembly having a corresponding/respective recess. In this context, the radially inner surface of the recess may point in a radially outward direction, i.e. away from the rotational axis.

The hub portion may be said to have a castellated shape. Such a castellated shape may have recesses and crests. Each recess may be shaped to accept a locating portion of a rotor blade assembly. The locating portion may include at least the blade assembly attachment web. The locating portion may also include a radially extending portion of adjacent aerofoil members.

In such an arrangement, each crest of the hub portion may form a circumferentially extending gas-washed surface (i.e. a surface that extends in a substantially circumferential-axial direction) between aerofoil members.

The rotor blade stage may further comprise a plurality of attachment covers. Each rotor blade assembly may have a corresponding attachment cover. Each blade assembly attachment web may be fixed in position between its respective mounting surface and attachment cover. This may be a particularly accurate, secure and uncomplicated arrangement for attaching the rotor blade assembly to the engine.



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Each attachment cover may have a radially inner surface (which in this case may point towards the rotational axis of the engine) and a radially outer surface (which in this case may point away from the rotational axis of the engine). The radially outer surface of the attachment cover may be a gas-washed surface. For example, the radially outer surface may form at least a part of the inner surface of the annular flow passage in which the fan rotates during use. The radially inner surface of each attachment cover may correspond to (for example cooperate with) the radially outer surface of the respective blade assembly attachment web. The attachment cover may be fastened to the hub portion, thus locating/trapping the rotor blade assembly therebetween. Purely by way of example only, the attachment cover may be fastened to the hub portion using one or more fasteners, such as threaded fasteners such as bolts.

According to an aspect, there is provided a gas turbine engine comprising a rotor blade assembly and/or rotor blade stage as described herein. As mentioned elsewhere herein, the rotor blade stage may be a fan stage. The gas turbine engine may thus be a turbofan engine, which may have a bypass duct. Of course, the rotor blade assembly and/or rotor blade stage may be provided to any type of gas turbine engine.

In arrangements in which the rotor blade assembly/stage is provided to a turbofan gas turbine engine, the gas turbine engine may further comprise a nose cone. In such an arrangement, each rotor blade assembly may be clamped between the hub portion and the nose cone. For example, the blade assembly attachment web may be clamped between the hub portion and the nose cone. For example, the blade assembly attachment web may be slid into position in the hub portion (for example into a slot), and the nose cone may then be slid into position (for example axially) in order to retain the rotor blade assembly. The nose cone may have a dedicated protrusion (for example a ring), which may cooperate with the hub portion and the blade assembly attachment web in order to locate/fix the rotor blade assembly in place.

According to an aspect, there is provided a method of assembling a rotor blade stage of a gas turbine engine. The method comprises clamping a plurality of rotor blade assemblies as described by way of example herein between a hub portion of the gas turbine engine and an attachment fixture. The attachment fixture may be either an attachment cover or a nose cone of the gas turbine engine. The attachment cover and/or nosecone may be as described above and elsewhere herein, for example. Thus, for example, the rotor blade stage being assembled may be said to comprise an attachment fixture (which may be either an attachment cover or a nose cone, for example), which has a radially outer surface that, in use, is a gas-washed surface.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying Figures, in which:

FIG. 1 shows a partially cut-away version of a gas turbine engine;

FIG. 2 shows a cross section through a gas turbine engine;

FIG. 3 shows a perspective view of a rotor blade assembly;

FIG. 4 shows an exploded view of a rotor blade assembly together with a cross-section through a hub portion;

FIG. 5 shows a cross section through a hub portion, a rotor blade assembly, and an attachment panel; and

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FIG. 6 shows a cross section through a hub portion, a rotor blade assembly, and a nose cone.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 2, a ducted fan gas turbine engine generally indicated at **10** has a principal and rotational axis X-X. The engine **10** comprises, in axial flow series, an air intake **11**, a fan **12**, an intermediate pressure compressor **13**, a high-pressure compressor **14**, combustion equipment **15**, a high-pressure turbine **16**, and intermediate pressure turbine **17**, a low-pressure turbine **18** and a core engine exhaust nozzle **19**. The engine also has a bypass duct **22** and a bypass exhaust nozzle **23**.

The gas turbine engine **10** works in a conventional manner so that air entering the intake **11** is accelerated by the fan **12** to produce two air flows: a first air flow A into the intermediate pressure compressor **13** and a second air flow B which passes through the bypass duct **22** to provide propulsive thrust. The intermediate pressure compressor **13** compresses the air flow A directed into it before delivering that air to the high pressure compressor **14** where further compression takes place.

The compressed air exhausted from the high-pressure compressor **14** is directed into the combustion equipment **15** where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive, the high, intermediate and low-pressure turbines **16**, **17**, **18** before being exhausted through the nozzle **19** to provide additional propulsive thrust. The high, intermediate and low-pressure turbines **16**, **17**, **18** respectively drive the high and intermediate pressure compressors **14**, **13** and the fan **12** by suitable interconnecting shafts.

The compressor and turbine each comprise rotor stages and stator stages. In FIG. 2, a stator stage is labelled **30** in the intermediate stage compressor **13** and a rotor stage is labelled **40**. The fan **12** may be said to be an example of a rotor stage. The fan **12** may be the most upstream of the rotor stages in an engine.

The fan **12** comprises a plurality of fan blades **120**, as shown in both FIG. 1 and FIG. 2. The fan blades **120** are provided as a pair of fan blades **120** in a fan blade assembly **100**. Such a fan blade assembly **100** is shown in greater detail in FIG. 3. The fan blade assembly **120** is an example of a rotor blade assembly **120** that is in accordance with aspects of the invention. The fan blades **120** may be referred to as aerofoil members **120**. A plurality of fan blade assemblies **100** may be provided in a gas turbine engine **10** to produce a fan stage **12**.

The fan blade assembly **100** comprises blades (or aerofoil members) **120**, each extending from a root **122** to a tip **124**. The root **122** may be a root portion **122**, and the tip **124** may be a tip portion **124**. The aerofoil members **120** may be of any shape and/or design. For example, the aerofoil members **120** may be any design of fan blade **120**, as shown in the FIG. 3 example. Indeed, the aerofoil members **120** may be any design/shape of rotor blade, for example for a compressor stage **30** or a turbine stage **40** of a gas turbine engine **10**. The blades **120** of the rotor blade assembly **100** form adjacent blades **120** of the rotor stage **12** when the rotor stage **12** is assembled.

A blade assembly attachment web **130** extends between the two fan blades **120**. The blade assembly attachment web **130** may extend between the roots **122** of the blades **120**, as in the example shown in FIG. 3. As explained in greater detail elsewhere herein (for example in relation to FIG. 4, by

way of example), the blade assembly attachment web may be used for attaching the fan blade assembly to the gas turbine engine **10**, for example to a hub and/or shaft of the gas turbine engine (directly or indirectly).

Rotor blade assemblies according to aspects of the invention, including the rotor blade assembly **100** described herein, may comprise (and/or may be formed or manufactured using) a fibre-reinforced composite material, such as a fibre-resin composite. The fibre-reinforced composite material may be, for example, an organic matrix composite, such as a carbon fibre based composite. Any suitable method may be used to form the fibre-reinforced composite rotor blade assemblies **100** such as, for example, impregnating the fibres with the resin, forming the desired shape and then curing in an autoclave (a so-called "pre-preg" method), or a dry-fibre and resin-transfer method, or an Automated Fibre Placement (AFP) method.

Where the rotor blade assembly **100** is manufactured using a resin transfer method using a dry fibre perform, the outer plies may, for example, be formed from a braided tube slid over the individual plies. This optional feature may provide a continuous outer layer with no ply edges, thereby reducing/substantially eliminating the possibility of delamination. Additionally or alternatively, dry fibre preforms could of have through thickness reinforcement added to the structure in the form of tufting or stitching, z-pinning and/or direct insertion.

The fibres in the rotor blade assembly **100** may be arranged in any manner, as desired. By way of example only, in the rotor blade assembly **100** may comprise at least some fibres that extend from the tip **124** of one of the blades **120** through the assembly **100** to the tip **124** of the other blade **120**. Such fibres may extend through the blade assembly attachment web **130**. Such fibres may extend from a first tip **124** in a radially inward direction along a first blade **120**, then in a substantially circumferential direction through a blade assembly attachment web **130**, then in an outwardly radial direction from the root **122** to the tip **124** of the other blade **120**. Such fibres may be continuous from the tip **124** of one blade through to the tip **124** of the other blade. Such an arrangement may be particularly strong and/or may allow the shape of the rotor blade assembly **100** to be retained during use. For example, the at least some of the fibres may be arranged so as to be aligned with the main load direction during use (which may be in the radial direction of the engine, for example due to centripetal force during rotation of the blade assembly about the engine axis). Additionally or alternatively, the fibres may be aligned in other directions (such as at 45 degrees or 90 degrees to this direction), for example to provide strength in other directions, and/or chopped fibres may be used.

Optionally, during manufacture, sacrificial material (for example sacrificial layers of fibres) may be provided to allow the component to be machined into a final shape if required. For example, such sacrificial material may be provided to the blade assembly attachment web **130**.

At least a part of the rotor blade assembly **100** may comprise a coating, for example a protective coating. For example, the blades/aerofoil members **120** at least may comprise a protective coating, such as an erosion protection coating, which may form (or be applied to) the surface thereof. Such an erosion protection coating may comprise, for example, a fluoroe elastomer, a thermoplastic and/or polyurethane.

Additionally or alternatively, the aerofoil members **120** may comprise leading edge protection. Such leading edge

protection may take any suitable form, for example metallic strips bonded to the surface of the aerofoils at their leading edge.

The rotor blade assembly **100** may additionally or alternatively comprise a glass fibre skin, which may be woven.

Such coatings and/or skins may not be visible on the surface of the rotor blade assembly and so they are not explicitly labelled in the Figures. However, such coatings/skins may be visible in some arrangements.

The blade assembly attachment web **130** may have a radially outer surface **132** and a radially inner surface **134**. The radially outer surface **132** may be referred to as an upper surface, or the surface which points towards the aerofoil members **120**. The radially inner surface may be referred to as an inner surface, or the surface that points away from the aerofoil members **120**. Referring now to FIGS. **4**, **5** and **6**, the radially inner surface **134** may be configured (for example shaped) to correspond to (or cooperate with) a mounting surface **210**. The rotor blade assembly may be mounted on the mounting surface **210** in order to be attached onto the rest of the gas turbine engine. The mounting surface **210** (or at least a part thereof) may be a part of a rotatable hub **200**. The rotatable hub **200** may be a part of, or may be provided on, a rotating shaft. The rotating shaft may be connected to a part of a turbine of the gas turbine engine **10** (for example directly or through a gearbox).

The radially inner surface **134** of the rotor blade attachment web **130** and/or the mounting surface **210** may be, for example, an annular segment or a frusto-conical segment and/or may comprise a location feature for locating the attachment web **130** in position relative to the hub **200**.

The hub **200** (which may be referred to as a hub portion **200**) may comprise a plurality of mounting surfaces **210**, as shown in the FIG. **4** example. The hub portion may thus have a castellated outer surface, with a mounting portion (including the blade assembly attachment web **130**) of the rotor blade assembly **100** fixed into the troughs, or recesses, of the castellated surface. In one or more embodiments, the castellated outer surface includes dividing portions **211** on either side of the mounting portion that effectively divide the mounting portions from each other, as well as the rotor blade assembly and respective attachment web from other rotor blade assemblies and their respective attachment webs when the rotor blade assemblies are located onto the hub **200**. The dividing portions **211**, as shown in FIG. **4**, can project in a radially outward direction away from the mounting portions of the hub **200**. A rotor blade assembly **100** may be provided to (for example mounted on) each of the mounting surfaces **210** in order to form the fan stage **12**. A gas turbine engine **10** may comprise any number of rotor blade assemblies **100** and/or corresponding mounting surfaces **210** in the fan stage **12**.

The mounting surface **210** may be formed in any suitable manner. For example, as shown in FIG. **4**, the mounting surface **210** could be a radially inner surface (i.e. the surface that faces away from the engine rotational axis X-X) of a recess **220** formed in the hub portion **200**.

FIGS. **5** and **6** show two examples of how the rotor blade assembly **100** may be attached to the gas turbine engine **10**, via the blade assembly attachment web **130**.

In FIG. **5**, the blade assembly attachment web **130** is fixed in position using an attachment cover **300**. The blade assembly attachment web **130** may be trapped, or fixed, in position between the attachment cover **300** and the mounting surface **210**. In the FIG. **5** example, the blade assembly attachment web **130** may be fixed between the attachment cover **300** and the mounting surface **210** by moving the attachment cover

**300** in the direction of arrow **310**, and then fixing it in position. The attachment cover **300** may be fixed in position using, for example, one or more fasteners **320** (which may be threaded) and one or more corresponding receiving holes **330**. The receiving holes **330** may be provided in the hub **200**, for example in a recess in the hub for receiving the attachment cover **300**. Thus, the rotor blade assembly **100** may be fixed in position without having to modify the blade assembly attachment web **130** (or indeed any part of the assembly **100**), thereby not compromising the properties of the rotor blade assembly **100**. An outer radial surface **302** of the attachment cover **300** may form a gas washed surface when the gas turbine engine **10** is in use.

FIG. 6 shows an alternative arrangement for attaching the rotor blade assembly **100** in position. Again, the blade assembly attachment web **130** need not itself be modified in the FIG. 6 arrangement. In particular, in the FIG. 6 arrangement, the blade assembly attachment web **130** is trapped (or fixed) in position between a hub **200** and a nose cone **400**. In the FIG. 6 example, the blade assembly attachment web is fixed between a mounting surface **210** and protrusions **202**, **402** provided on the hub **200** and the nose cone **400**. As shown in FIG. 6, one or both of the protrusions **202**, **402** may have a radially outer surface that, in use, is a gas-washed surface. It will be appreciated that alternative arrangements may be used. Purely by way of example, some arrangement may not require a protrusion **202** on the hub **200**, such that the blade assembly attachment web **130** is trapped between the mounting surface **210** and a protrusion on the nose cone **400**. In the FIG. 6 example, the nose cone **400** is moved towards the hub **200** in the direction of arrow **410** during assembly, and fastened to the hub **200** using any appropriate fastener **420**, **430**, such as one or more threaded fasteners **420** and corresponding receiving holes **430**.

The attachment cover **300** and the nose cone **400** may be examples of attachment fixtures. Such attachment fixtures may be made from any suitable material, including, for example metal and/or composite, such as fibre (for example organic fibre) and resin composite material, for example fibre reinforced organic matrix material or compression moulding compound.

The arrangements shown in FIGS. 4 to 6 for fixing rotor blade assemblies **100** to the gas turbine engine **10** in order to form a fan stage **12** are examples of those which could be used. It will be appreciated that many other arrangements could be used.

Rotor blade assemblies according to the invention may take many different forms, which are not limited to those described above by way of example in relation to the Figures (and elsewhere herein). For example, a rotor blade assembly may comprise a reinforcement web which may extend between the aerofoil members **120**. Such a reinforcement web (not shown in the Figures) may, for example, extend between the rotor blades **120** at any position along their span, i.e. at any radial position, including, for example, at mid-span and at the blade tips. Of course, some examples may not have a reinforcement web at all, such as the examples shown in the Figures.

The rotor blade assembly **100** has been described herein largely in relation to a fan stage **12**. However, the rotor blade assembly **100** could be used in any rotor blade stage, for example a rotor blade stage of a compressor or a turbine of a gas turbine engine.

Where reference is made herein to an engine or a gas turbine engine, it will be appreciated that this term may include a gas turbine engine/gas turbine engine installation and optionally any peripheral components to which the gas

turbine engine may be connected to or interact with and/or any connections/interfaces with surrounding components, which may include, for example, an airframe and/or components thereof. The gas turbine engine may be any type of gas turbine engine, including, but not limited to, a turbofan (bypass) gas turbine engine, turbojet, turboprop, or open rotor gas turbine engine, and for any application, for example aircraft, industrial, and marine application.

It will be appreciated that many alternative configurations and/or arrangements of rotor blade assemblies **100**, rotor blade stages, and attachment arrangements **300**, **400** in addition to those explicitly described herein may fall within the scope of the invention. Furthermore, any feature described and/or claimed herein may be combined with any other compatible feature described and/or claimed in relation to the same or another embodiment.

I claim:

1. A rotor blade stage and a rotor blade assembly for a gas turbine engine, wherein the rotor blade assembly comprises:
  - two aerofoil members, each extending from a root to a tip; and
  - a blade assembly attachment web extending between the roots of the two aerofoil members and arranged for use in attaching the rotor blade assembly to the rest of the gas turbine engine in use, wherein:
    - the two aerofoil members and the blade assembly attachment web are integrally formed using a fiber-reinforced composite material; and
    - wherein the, rotor blade stage comprises:
      - a plurality of the rotor blade assemblies;
      - a rotatable hub portion onto which each of the plurality of rotor blade assemblies is fixed using the blade assembly attachment web of each of the plurality of rotor blade assemblies, wherein:
        - the rotatable hub portion comprises a plurality of mounting surfaces,
        - the plurality of mounting surfaces are separated from each other by dividing portions which project in a radially outward direction from the rotatable hub portion thereby dividing the blade assembly attachment web of each of the plurality of rotor blade assemblies, and
        - the blade assembly attachment web of each of the plurality of rotor blade assemblies having a radially inner surface that is shaped to cooperate with a respective one of the plurality of mounting surfaces so as to locate each of the plurality of rotor blade assemblies on the rotatable hub portion.

2. The rotor blade stage and the rotor blade assembly according to claim 1, wherein the blade assembly attachment web has the radially inner surface and a radially outer surface with respect to a rotational axis of the gas turbine engine in use, the radially inner surface being shaped to cooperate with the plurality of mounting surfaces of the gas turbine engine to allow the plurality of rotor blade assemblies to be located in position in the gas turbine engine.

3. The rotor blade stage and the rotor blade assembly according to claim 1, wherein the two aerofoil members are fan blades, wherein the gas turbine engine comprises a turbofan gas turbine engine, and the plurality of rotor blade assemblies are part of a fan stage of the turbofan gas turbine engine.

4. The rotor blade stage and the rotor blade assembly of the gas turbine engine according to claim 1, wherein each

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mounting surface of the plurality of mounting surfaces is formed by a radially hub outer surface of a respective recess in the rotatable hub portion.

5 5. The rotor blade stage and the rotor blade assembly according to claim 1, further comprising a plurality of attachment covers, each rotor blade assembly of the plurality of rotor blade assemblies having a corresponding attachment cover, wherein:

10 each blade assembly attachment web is fixed between its respective mounting surface and attachment cover.

6. The rotor blade stage and the rotor blade assembly according to claim 5, wherein each of the plurality of attachment covers has a radially outer surface which, in use, is a gas-washed surface.

15 7. The rotor blade stage and the rotor blade assembly according to claim 1, wherein the rotor blade stage is a fan stage of a turbofan gas turbine engine.

8. A gas turbine engine comprising the rotor blade stage and the rotor blade assembly according to claim 1.

20 9. A method of assembling a rotor blade stage of a gas turbine engine comprising:

integrally forming a rotor blade assembly using fiber-reinforced composite material, wherein the rotor blade assembly comprises:

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two aerofoil members, each extending from a root to a tip; and

a blade assembly attachment web extending between the roots of the two aerofoil members;

5 locating a plurality of rotor blade assemblies on a rotatable hub portion by a radially inner surface of the blade assembly attachment web that is shaped to cooperate with a respective one of a plurality of mounting surfaces on the rotatable hub portion, wherein

10 the plurality of mounting surfaces are separated from each other by dividing portions which project in a radially outward direction from the rotatable hub portion thereby dividing the blade assembly attachment web of each of the plurality of rotor blade assemblies; and

15 clamping the blade assembly attachment web of each of the plurality of rotor blade assemblies between the rotatable hub portion and a respective attachment cover.

20 10. The method of assembling the rotor blade stage of the gas turbine engine according to claim 9, wherein the attachment cover has a radially outer surface which, in use, is a gas-washed surface.

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